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13. ABSTRACT *(Maximum 200 words)*

A femtosecond Ti:Sapphire laser has been constructed for an investigation of the transport of nonequilibrium, nonthermal, electronic carriers in metallic thin film nanostructures.

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PHONONS, POLARITONS, ELECTRONIC CARRIERS & LASER DAMAGE

FINAL TECHNICAL REPORT

W. E. BRON

AUGUST 1, 1996

U.S. ARMY RESEARCH OFFICE

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UNIVERSITY OF CALIFORNIA, IRVINE

Recent advances in the observation of quasiparticle transport in thin metallic films have considerably increased the understanding of nonequilibrium, nonthermal quasiparticle transport. Most important is the significant new information on the dynamics and the transport which occurs in the first few hundred femtosecond. It has become possible to experimentally segregate a component of the transport which propagates essentially without any interaction for distances of up to ~500 nm in single crystalline gold films. The dynamics and transport observed experimentally is accounted for through an application of Fermi Liquid Theory.

One of the reasons for conducting these experiments is the realization that almost all electronic contacts in modern logic are deposited on substrates by various means. With the approach of the optical computer, switching times will approach the femtosecond domain and, therefore, to nonequilibrium nonthermal quasiparticle transport. The basic properties of such nonequilibrium transport define the limiting properties of the contacts.

Experimentation has so far been conducted with a time resolved, 100 fs, dye jet laser system consisting of a mode-locked Nd:YAG master oscillator amplified through a Nd:YAG regenerative amplifier. This system is inherently noisy whereas typical signal strength is of the order of 10^{-5} to 10^{-7}. In order to overcome the low signal to noise, we have constructed a Ti:Sapphire femtosecond laser system which self modulates (and at times self starts) at repetition rates of the order 100 MHz.

Supporting Information

The preparation of nanostructure structures is also compared to the evaporated thin films discussed above. For this purpose we are forging an interdisciplinary collaboration with Chen Tsai at the University of California, Irvine, who is a Professor of Electrical and Computer Engineering. Prof. Tsai is an internationally recognized expert in integrated acoustooptics and magnetooptics within the general field of microoptics. The facilities include a state-of-the-art MBE (Molecular Beam Epitaxy) machine particularly oriented to optical phenomena. Prof. Tsai's group will prepare the samples required by our research activity on the ultrashort transient excitation of nonequilibrium, and nonthermal properties of metallic thin film structures.

Natural extensions of our work on thin metallic films includes effects unique to nanostructures, i.e., effect of confinement, carrier scattering and relaxation processes, scattering at imperfections and boundaries. Information on carrier transport is obtained as a function of time ($\sim$10 to 100 femtosecond resolution), optical excitation frequency, excitation intensity, and variation of individual nanostructures.

A second major accomplishment (so far unpublished) of our research is the detection of metal-metal interfaces through electron transport spectroscopy (ETS). In these experiments advantage is taken of the fact that quasiparticle transmissivity varies among different metallic films. For example, quasiparticle-quasiparticle, and quasiparticle-phonon scattering times differ between gold films and other (e.g. Ti) films of the same thickness. Therefore, if one compares the transparency of purely gold and Au-Ti-Au multilayer, a lower transmissivity is observed between the multilayer and the gold film, all other factors such as total film thickness being the same. We have detected by these means a Au-Ti interface by constructing a Au film in contact with a Au-Ti-Au multilayer. Measurements of the arrival time of ballistic and/or scattered electron transport has been achieved by measuring the electron transport arrival time discussed above, as the probe laser beam is rastered from the pure gold film, across the Au-Au-Ti-Au interface and into the Au-Ti-Au multilayer. The interface is readily detected with a resolution of $\sim$10 μm. Other defects, such as surface scratches can be detected on either the Au film or the Au-Ti-Au multilayer. it is important to note that the resolving element here is the quasiparticle transport, not light which is in any event limited to the skin depth (~15 nm in gold). Thus defects and interfaces can be detected by these means even though the material is optically absorptive. Experimentation will proceed with, at least initially, gold nanostructures because such structures are among the easiest to produce, and because much of the experimental and theoretical background has been achieved in gold films.

Upgrade of Existing Laser Facility

The current femtosecond laser facility available over the past decade in the PI's research laboratory consists (see Fig. 1) of an Nd:YAG mode-locked master oscillator whose doubled green beam is split into two synchronized picosecond or femtosecond tunable dye jet lasers. The output of either laser beams, or both, can be amplified, up to a factor of 10^4; through an Nd:YAG regenerative amplifier. This system is inherently noisy due to thermal lensing of the Nd:YAG and the dye jet gain medium. These noise limitations make it impossible to resolve small deviations in the detected signals strength.

Upgrading of Femtosecond Laser Facility

In order to overcome the associated problems of the Nd:YAG based laser system, we have essentially completed a $Ti{:}Al_2O_3$ femtosecond laser system illustrated in Fig. 2.

The $Ti{:}Al_2O_3$ laser is pumped by an all linear CW A^{2+} gas laser. The pump is focused by the lens into a Brewster cut $Ti{:}Al_2O_3$ crystal 4.75 mm long. The BBO harmonic doubler with focusing lenses is the only part which has not been assembled at the time of this report. P_1 and P_2 are the usual 4-prism set typically used to compensate for GVD. M_1 is the high reflection and M_2 is the output coupler. This laser system follows the one developed by Prof.

M. M. Murnane (private communication). Other properties of the $Ti:Al_2O_3$ system are as follows:

I. Pump

a) All lines Ar^+ Ion laser with 6.0W average power

II. $Ti:Al_2O_3$ laser output

a) 500 mW average output power, self-mode-locked, centered at around 790 nm (without intracavity SHG).

b) Linewidth $\approx$ 20 nm

c) 100 fsec duration pulses, $\approx$ 80 MHz repetition rate

d) Crystal Dimension: 4.75 mm long

e) Output frequency with doubler is $\sim$415 nm

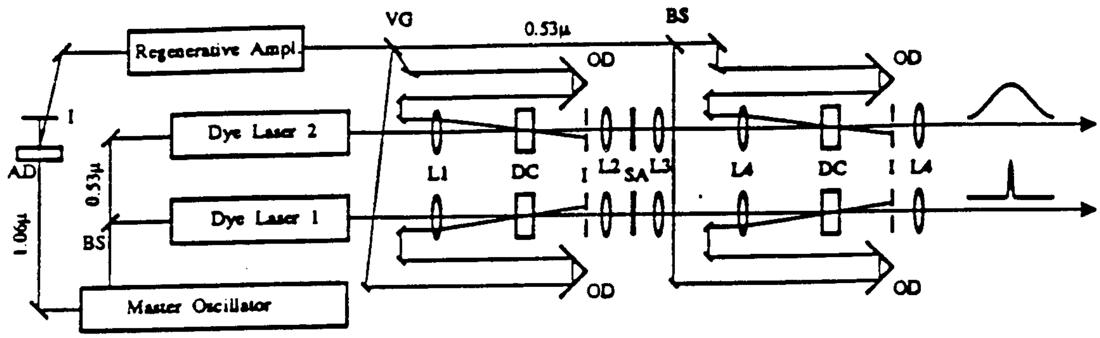

Figure 1: Sketch of a dual, synchronous, tunable amplifier ultrashort pulsed laser system. The master oscillator (ML) is a mode-locked Nd:YAG laser, DL are two tunable dye lasers, RA is a regenerative Nd:YAG amplifier, AD is an acousto-optic deflector, BS are beam splitters, L are lenses, DC are flow through dye laser quvettes, SA saturable absorber, OD optical delays, I are irises and VG are glass wedges.

Titanium Sapphire Laser

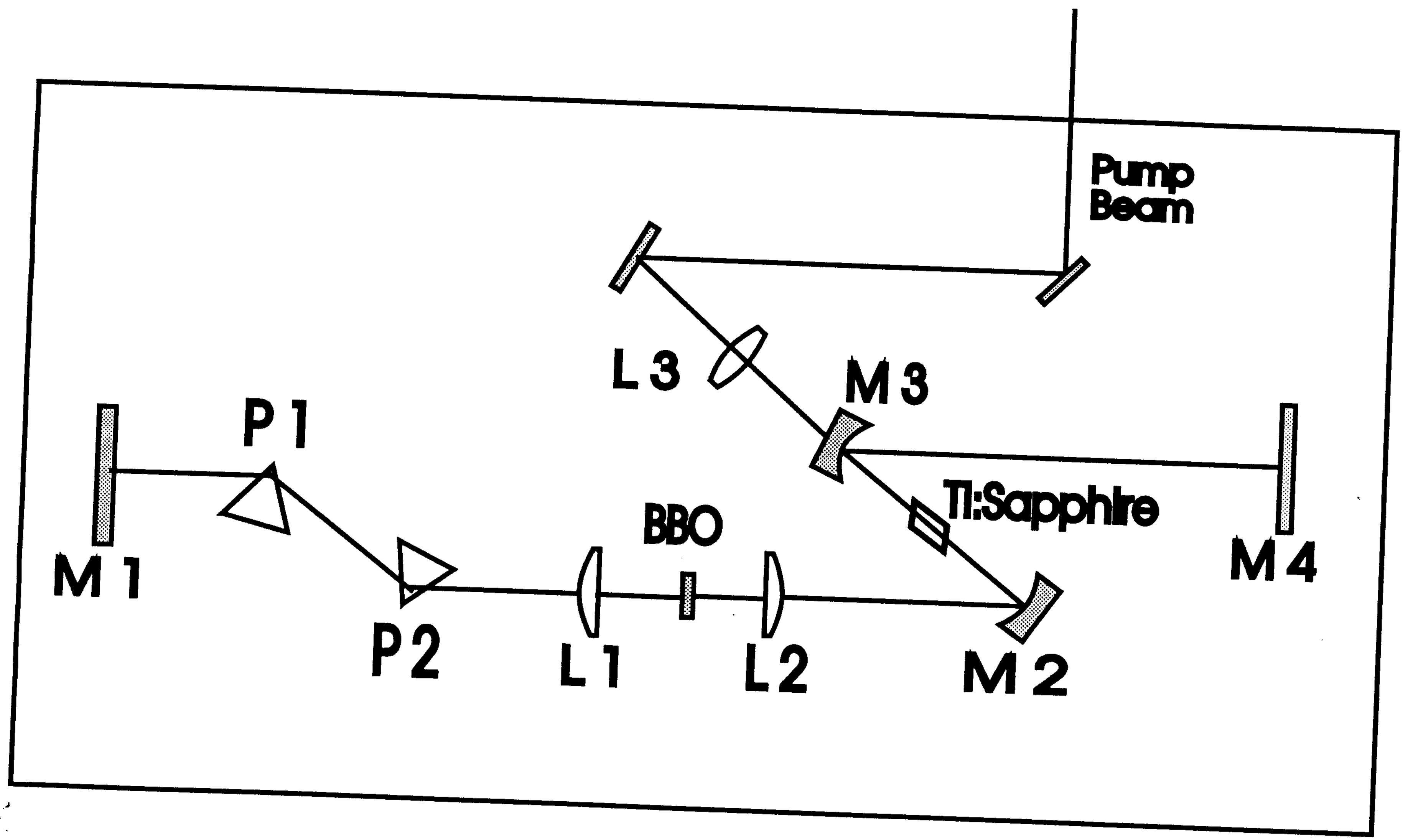

Fig. 2 Sketch of $Ti:Al_2O_3$ laser